

Table 4.3-3. Possible Damage to Structures From Sonic Booms (Haber/Nakaki 1989)

| Sonic Boom Overpressure Nominal (psf) | Type of Damage | Item Affected |
|--|---------------------------------|---|
| 0.5 - 2 | Cracks in plaster | Fine; extension of existing; more in ceilings; over door frames; between some plaster boards. |
| | Cracks in glass | Rarely shattered; either partial or extension of existing. |
| | Damage to roof | Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole. |
| | Damage to outside walls | Existing cracks in stucco extended. |
| | Bric-a-brac | Those carefully balanced or on edges can fall; fine glass, e.g., large goblets can fall and break. |
| | Other | Dust falls in chimneys. |
| 2 - 4 | Glass, plaster, roofs, ceilings | Failures show which would have been difficult to forecast in terms of their existing localized condition. Nominally in good condition. |
| 4 - 10 | Glass | Regular failures within a population of well-installed glass; industrial as well as domestic greenhouses. |
| | Plaster | Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured, or very old plaster. |
| | Roofs | High probability rate of failure in nominally good state, slurry-wash; some chance of failures in tiles on modern roofs; light roofs (bungalow) or large area can move bodily. |
| | Walls (out) | Old, free standing, in fairly good condition can collapse. |
| | Walls (in) | Inside ("Party") walls known to move at 10 psf. |
| Greater than 10 | Glass | Some good glass will fail regularly to sonic booms from the same direction. Glass with existing faults could shatter and fly. Large window frames move. |
| | Plaster | Most plaster affected. |
| | Ceilings | Plaster boards displaced by nail popping. |
| | Roofs | Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gale-end and will-plate cracks; domestic chimneys dislodged if not in good condition. |
| | Walls | Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage. |
| | Bric-a-brac | Some nominally secure items can fall; e.g., large pictures, especially if fixed to party walls. |

Preliminary Noise and Sonic Boom Footprints

Preliminary noise and sonic boom footprints were overlaid to scale on maps of EAFB, WSMR, and the ER in order to provide preliminary reference information. The maps are shown in Appendix D. No impact on any of the ranges is expected from noises or sonic booms generated during takeoff and ascent. Final determination of these impact off-range are deferred to EA-II.

Noise Effects on Animals

Effects of noise on animals are of concern at any of the three ranges, because of endangered and other listed species present near flight operations. Flight noise from the X-33 vehicle is of short duration and infrequent. Available data and field observations at active space vehicle and missile launch facilities suggest that the type of noise anticipated with X-33 flight operations will produce no cumulative effect on domestic animals and wildlife (NASA 1972, WSMR 1996-A). Startle effects should be of short duration without any substantial or permanent adverse effects.

4.3.2 Off-Site Safety

Flight Safety

The primary off-site flight safety related issue is flying an experimental spaceplane over private property and the general population. As part of the test program, flights will be traveling out of range-controlled airspace. In the case of EAFB and WSMR, once the X-33 leaves the range, it will fly over members of the general population. Takeoff from ER will be over water; however, depending on the final destination, there may be some population overflight in marine shipping lanes and at the landing site.

Since the area covered by each flight is so large, it is impractical to avoid all inhabited areas. The primary method of reducing risk is to build a spaceplane designed for very high reliability. X-33 is being designed to meet reliability requirements that exceed those of existing launch vehicles. A generic X-33 spaceplane model (see Appendix C) was used in preliminary computer simulations of off-range test flights over generic flight corridors (Figure 4.3-6) to determine potential feasibility of meeting acceptable range safety risk criteria.

Preliminary simulations by WSMR Range Safety have considered the risk to the public of explosive inflight breakup of the spaceplane. Risk data from these simulations indicate that it is potentially feasible to fly a LOX/LH₂ spaceplane over selected flight corridors. After a single spaceplane concept is selected, programmatic risk acceptance criteria will be developed in coordination with the lead range, any other affected range, X-33 Program Office and the Industry Partner. Simulations of all reasonable failure modes will be performed using the specific design and flight paths to determine where programmatic risk acceptance criteria are met. Analysis of maximum flight path deviation and debris dispersion will also be performed. Results will be included in EA-II. Risk will be mitigated through the use of a 3-phase envelope expansion program previously described in Section 2.2.4.

X-33 will have abort capability to make a safe landing in the event of a recoverable failure. Abort sites will be identified throughout the off-range flight path.



Figure 4.3-6. Representative X-33 Flight Paths

During all test flights, X-33 will have an onboard flight management system to allow controlled flight termination in the event of a non-recoverable system failure. Flight termination methods are under evaluation. Nondestructive methods such as fuel cutoff are preferred.

Non-Flight Safety

Non-flight safety issues involve potential hazards to personnel and the general public at landing and abort sites. These hazards will be handled in the same manner as on-site hazards through compliance with OSHA and other applicable health and safety requirements. In the case of abort sites and non-Government-owned landing sites, agreements with local police, fire and rescue organizations will be required. Training in any unique hazards presented by X-33 will also be required by local organizations. ES/QD separation requirements may also apply at these sites depending on residual fuel onboard at landing, mode of return to primary site requirements, etc. In the event of an abort, immediate surrounding areas may have to be cleared until the fuel is removed and the spaceplane is "safed." The extent of the clear area will depend on how much fuel is left onboard. Ensuring that non-flight health and safety issues at off-site locations are adequately addressed will involve contingency planning and cooperation with local authorities.

4.4 Global Environment

4.4.1 Troposphere

The major combustion product of X-33 test flights as well as a successor LOX/LH₂ RLV system is water. Although water vapor is a greenhouse gas, it is abundant in the troposphere. Additional amounts of water vapor to the troposphere from either X-33 or an operational RLV system would be minute. The X-33 or RLV would not contribute any other quantifiable trace greenhouse gas. Therefore, no impact to greenhouse warming from either X-33 or a successor RLV is expected.

4.4.2 Stratosphere

A spaceplane concept previously under consideration for development in the early 1990's was called the National Aero-Space Plane (NASP). Jackman, Douglass, and Brueske (1992) modeled NASP's potential effect on stratospheric ozone. NASP, whose prototype forerunner was designated "X-30," is approximately analogous to X-33 and was baselined with a LOX/LH₂ propulsion system. NASP was projected to have an approximate gross liftoff weight (GLOW) of 147,000 kg (325,000 lb), which is in the approximate GLOW range of X-33 spaceplane concepts. Yearly average global total ozone decreases were computed to be a maximum of 9×10^{-5} percent for 40 NASP test flights per year. The minimal perturbation to stratospheric ozone was attributed to a small increase of stratospheric water production (maximum 0.1 percent).

In addition, Jackman, Considine, and Fleming (1995) modeled a theoretical aerospace vehicle with comparable size and total approximate liftoff thrust to the Space Shuttle, except the propulsion system was based on using LOX/LH₂/RP-1. Eight annual theoretical vehicle and eight Space Shuttle launches using the same trajectories and atmospheric conditions were assumed. Based on simulation results, ozone reduction in the northern polar latitudes due to the LOX/LH₂/RP-1 vehicle concept would be 6,000 times less than that produced by an equivalent number of Shuttle launches. On a yearly average global basis, this vehicle concept would produce 4,000 times less

ozone reduction than an equivalent number of Shuttle launches under the same conditions. Since the water contribution to ozone depletion from the vehicle concept was more important than the carbon species, such as carbon dioxide and carbon monoxide, it can be assumed that all SSTO concepts utilizing LOX/LH₂ would produce ozone reductions of approximately three orders of magnitude (1,000 times) less than current space launch vehicles whose exhaust products contain substantial quantities of chlorine. Therefore, adverse impacts on stratospheric ozone would be considered minimal for the X-33 and its successor RLV which will both fly up to altitudes exceeding 76 km (47 mi).

5.0 Pollution Prevention

Toxic Chemicals/Toxic Releases

In accordance with Executive Order (EO) 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," NASA developed pollution prevention strategies and incorporated them into "NASA Plan for Implementation of Executive Order 12856, Pollution Prevention and Community Right-to-Know" (NASA 1995-A).

NASA committed to strive to eliminate or reduce the production or acquisition of products which contain extremely hazardous substances or toxic chemicals. The Community Right-to-Know Act requires facilities that manufacture more than 11,300 kg (25,000 lb) or otherwise use more than 4,500 kg (10,000 lb) of listed toxic chemicals to publicly report their wastes and releases to EPA's Toxic Release Inventory (TRI). Federal facilities which exceed threshold requirements must develop goals to reduce releases and offsite transfers by 50 percent by the end of 1999. NASA adopted these goals. Table 5.0-1 summarizes 1995 TRI reporting for EAFB/AFFTC/DFRC, WSMR/WSTF, and the ER. These chemicals are targeted for release reduction goals.

In an effort to meet the goals set forth by EO 12856, many organizations have initiated projects affecting both the physical infrastructure and program/project operations on the ranges. Incorporating newer, more environmentally friendly processes produce benefits for many elements of the ranges involved. Some examples of technology used on the X-33 Program which will benefit pollution prevention efforts include:

- Use of graphite/epoxy composites in the manufacture of structural components to produce a structure which requires less propellant per unit weight to orbit. Composite processing is solvent free and does not require a high degree of corrosion protection; therefore, fewer materials containing volatile organic compounds are used.
- Ceramic matrix composites used to generate a stable TPS do not break apart, decompose or burn. The product is also reusable.
- Aqueous or terpene material used for surface preparation and cleaning replace or reduce the use of ozone depleting chemicals.
- LOX/LH₂ is a clean-burning propellant, releasing only water vapor into the environment.

NASA sponsors a significant number of R&D and materials substitution projects for the mutual benefit of the aerospace industry and the environment. (MSFC 1995-B)

Energy Efficiency

Pursuant to the Energy Policy Act of 1992 (Public Law 102-486 of October 24, 1992), each facility should strive to:

- reduce overall energy use by 30 percent by the year 2005 from their 1985 energy use levels;
- increase energy efficiency by 20 percent using 1990 as the baseline year;
- minimize the use of petroleum products; and
- increase the use of solar and other renewable energy sources.

Increased energy demand and use of petroleum products due to the X-33 Program will be minimal in comparison to the existing demands on each range.

Solid Waste Reduction and Recycling

Pursuant to EO 12873, "Federal Acquisition, Recycling, and Waste Prevention," each Federal facility is required to follow a waste reduction program and must have goals in place for solid waste reduction and recycling. In addition, each facility is requested to follow a waste reduction program.

EAFB and the ER operate their own recycling facilities. Solid waste generated by the X-33 Program will consist of debris and waste generated by program personnel during operations. The amount of waste generated will be small compared to daily waste produced by normal range operations.

Hazardous Waste and Oil Spill Prevention

In compliance with the Emergency Planning and Community Right-to-Know Act, each range has submitted an emergency planning notification to respective Local Emergency Planning Committees.

Table 5.0-1. 1995 Toxic Release Inventory for Ranges (Metric Tons)

| Chemical | WSMR/WSTF | EAFB/AFFTC/DFRC | ER |
|---------------------------|------------------|------------------------|-----------|
| 1,1,1-Trichloroethane | --- | --- | 12.54 |
| Acetone | 0.25 | --- | --- |
| Chlorodifluoromethane | --- | --- | --- |
| Dichloromethane | --- | --- | 8.56 |
| Dichlorotetrafluoroethane | --- | --- | 3.25 |
| Ethylene Glycol | --- | --- | 4.19 |
| Formaldehyde | --- | 24.33 | --- |
| Freon 113 | 3.51 | --- | 107.40 |
| Glycol Ethers | --- | 0.08 | --- |
| Hydrazine | 0.25 | --- | 0.65 |
| Hydrochloric Acid | --- | 17.16 | --- |
| Methyl Ethyl Ketone | --- | --- | 11.46 |
| Methyl Hydrazine | 0.25 | --- | 0.45 |
| Methyl Tert-Butyl Ether | --- | 0.02 | --- |
| Naphthalene | --- | --- | 0.09 |
| Propylene | --- | 15.22 | --- |
| Tetrachloroethylene | --- | --- | 9.20 |
| Toluene | --- | 16.46 | 4.43 |
| Xylene (mixed isomers) | --- | --- | 8.62 |
| Zinc (fume and dust) | --- | --- | 0.68 |

Based upon current usage levels, not including X-33 levels.

6.0 Environmental Justice

In accordance with EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," NASA set forth its Environmental Justice (EJ) policy and goals in the "National Aeronautics and Space Administration Environmental Justice Strategy" (PD 1994, NASA 1995-B). NASA committed to integrate EJ issues and concerns into its programs, policies, and activities. Each NASA Center is required to develop an EJ Implementation Plan which takes into account activities conducted at the Center and their environmental impacts, its organizational structure and existing processes, the nature of the surrounding community, and the most effective means of communication with external stakeholders.

The Army at WSMR and the Air Force at EAFB and CCAS must also comply with EO 12898. WSMR succinctly stated that its activities will be conducted in a manner that will not exclude persons from participation in, deny persons the benefit of, or subject persons to discrimination because of race, color, or national origin (WSMR 1996-A).

NASA is committed to avoid environmental impacts wherever possible and/or practicable and to mitigate unavoidable impacts as practicable in order to strive to maintain environmental balance and minimize risk to any sector of the public due to conduct of the X-33 test flight program. Following selection of the Phase II Industry Partner, NASA will address demographics around the recommended range(s) and ensure that EJ issues are a consideration prior to finalizing X-33 flight plans. Relevant EJ data and determinations will be included in EA-II.

7.0 References

- ANSI 1980 American National Standards Institute, "*Sound Level Descriptors for Determination of Compatible Land Use*," (Standard ANSI S3.23-1980), 1980.
- ASA 1988 American National Standards, "*Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1*," (Standard ASA S12.9-1988), 1988.
- Austin/Cook 1994 Aerospace America Magazine, article: "*SSTO rockets: Streamlining access to space*," prepared by Robert E. Austin and Stephen Cook, November 1994.
- CCAS 1986 U.S. Air Force, "*Environmental Assessment for the Complementary Expendable Launch Vehicle (CELV) at Cape Canaveral Air Force Station, Florida, Department of the Air Force, Headquarters Space Division*," (the CELV, i.e., 34D7, has been renamed the Titan IV), 1986.
- CCAS 1988 U.S. Air Force, "*Supplement to the Environmental Assessment for the U.S. Air Force, Space Division Titan IV Program at CCAFS*," Florida, 1988.
- CCAS 1991 United States Air Force, "*Interim Base Comprehensive Plan, Cape Canaveral Air Force Station, Land Use, Existing and Proposed*," prepared for Cape Canaveral Air Force Station by Johnson Controls World Services Inc., September 30, 1991.
- CCAS 1992 United States Air Force, "*Final Environmental Assessment, Expansion and Operation of CCAFS Landfill, Facility No. 23600*," prepared for Cape Canaveral Air Force Station by Johnson Controls World Services Inc., November 23, 1992.
- CCAS 1994-A United States Air Force, "*Environmental Assessment for the NAVSTAR Global Positioning System, Block IIR and Medium Launch Vehicle III, Cape Canaveral Air Station, Florida*," (Contract F33615-89-D-4003/Task 082), prepared for Department of the Air Force, Los Angeles Air Force Base, California, and Brooks Air Force Base, Texas, November 1994
- CCAS 1994-B United States Army Corps of Engineers, 45th Space Wing/CEV, Patrick Air Force Base, Florida, "*Historic Properties Survey, Cape Canaveral Air Force Station, Brevard County, Florida*," prepared for the United States Army Corps of Engineers by Ebasco Services, Incorporated, and New South Associates, March 31, 1994.